International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 04 | Apr 2025 www.irjet.net p-ISSN: 2395-0072

Framework for Waste-To-Energy Plant in urban planning : Circular Urban Metabolism approach

Sayana Shaiju[1], AR. Chippy Nicholas[2]

[1]PG Student of Architecture and Planning ,Government Engineering College, Thrissur,India
[2]Assitant Proffesor (Adhoc) of Architecture and Planning ,Government Engineering College, Thrissur,India

***

Abstract - *India Urban areas today face growing environmental stress due to rapid population growth and the increasing volume of municipal solid waste. Traditional waste management approaches are proving inadequate, calling for innovative, sustainable solutions. This study explores the integration of Waste-to-Energy (WtE) systems into urban planning through the lens of Circular Urban Metabolism (CUM)—a concept that reimagines waste as a resource and promotes circularity within urban systems.*

The research aims to develop a comprehensive framework that aligns WtE facilities with CUM principles to enhance sustainability, resource recovery, and public acceptance. Through an in-depth review of related concepts and terminology, analysis of national and international case studies—both successful and failed—and an evaluation of site suitability methods such as the Analytical Hierarchy Process (AHP), the study identifies key strategies for integrating circular thinking into WtE infrastructure.

The proposed conceptual framework offers a structured and adaptable model for urban planners, policymakers, and waste management authorities, supporting better design, decision-making, and community engagement in future WtE projects. This approach not only addresses pressing waste issues but also contributes to a more circular, energy-efficient, and resilient urban future.

Key Words: **Circular Urban Metabolism (CUM),Waste-to-Energy (WtE)**, **Urban Sustainability**, **Material Flow Analysis (MFA)**,**Circular Economy (CE)**,**Urban Metabolism (UM)**

1.INTRODUCTION

As cities continue to grow rapidly, they are producing more waste than ever before, putting immense pressure on traditional waste management systems. This growing crisis contributes to environmental pollution and the loss of valuable resources. To tackle this, the idea of Circular Urban Metabolism (CUM) offers a smarter way forward—treating waste not as a burden, but as a resource that can be reused or repurposed in a closed-loop system. Within this approach,

Waste-to-Energy (WtE) plants offer a practical solution by converting urban waste into usable energy. But while promising, WtE projects often face challenges—ranging from environmental concerns to public resistance. This study looks at how WtE plants can be better designed and integrated through the lens of CUM, aiming to reduce their negative impacts and build public trust. By aligning technology with circular thinking and community needs, cities can take a step toward cleaner, more efficient, and more livable urban environments.

1.1 Need of the study

The need for this study arise from urgent environmental challenges in urban areas due to rising waste generation and inefficient management. As cities expand, innovative waste management solutions are critical. CUM offers a framework to transform waste into a resource, but WtE plants often lack sustainable integration and community support. This study aims to reimagine WtE through circularity, identifying strategies to mitigate negative impacts and enhance public acceptance for a more sustainable urban future.

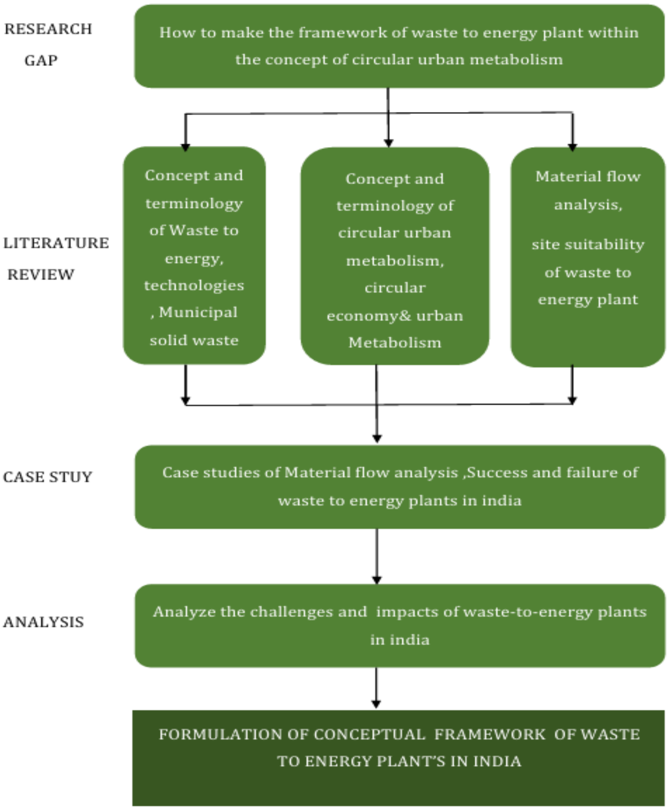
1.2 Aim

To develop a Framework for waste-to-energy (WtE) that aligns with the concept of Circular Urban Metabolism.

1.3 Objective

- To Study the Concept and Terminology related to Waste-to-Energy plants and circular urban metabolism .
- To identify and integrate Circular Urban Metabolism in waste-to-energy plants.
- To analyze the case studies of successful and failed waste to energy plant's in india.
- To Propose a conceptual framework for Waste to energy plant by using the concept of circular urban metabolism .

1.4 Methodology



1.5 Scope

- A clearer of the foundational concepts of Circular Urban Metabolism (CUM) and Waste-to-Energy (WtE), leading to better theoretical frameworks for future research.
- Identification of effective methods to integrate CUM principles into WtE plants, contributing to improved sustainability and resource management.
- By the evaluation of successful and failed WtE plants helps to avoid previous mistakes and replicate successes.
- The development of framework will provide practical guidance for policymakers and practitioners in designing and operating WtE systems more effectively and sustainably.

1.6 Limitations

- The availability of data on Waste-to-Energy (WtE) plants may impact the depth of case study analysis.
- This study primarily examines the existing policies and frameworks, providing an overview rather than an exhaustive analysis.
- The study focuses on specific Waste-to-Energy technologies, offering insights into their application and potential.
- The study does not include a detailed economic feasibility study or environmental impact assessment.

2. CIRCULAR URBAN METABOLISM (CUM)

Circular urban metabolism is a concept that refers to cities functioning as living organisms that consume, metabolize and excrete, breathe, distribute and protect themselves [1].First introduced by Abel Wolman in 1965, the idea was to measure what cities consume and what they produce as waste, so that we could better manage their environmental impact. Early studies in cities like Hong Kong and Brussels helped shape this concept by tracking the flow of materials and energy in and out of urban areas.

CUM builds on this by pushing for a circular approach, where waste is minimized, and resources are reused or recovered. This is especially important as cities today use around 70% of the world's resources and two-thirds of all energy. In this framework, Circular Economy (CE) principles—like reducing, reusing, and recycling—are applied to how cities function. The goal is to create systems that make smarter use of resources and support long-term balance between environmental needs and urban growth. By mapping the connections between materials, energy, and social dynamics over time and across different parts of a city, CUM helps us find where circular practices can make the biggest impact. Figure 1 is adapted from the Circular Urban Metabolism Framework by Giulia Lucertini and Francesco Musco[1]

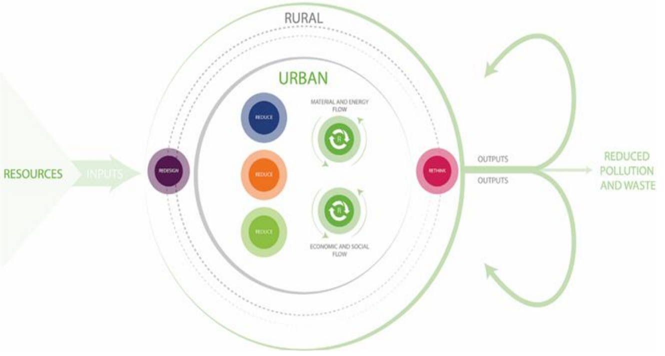


Fig -1: Framework for circular urban metabolism

2.1 Circular Economy Concept

The Circular Economy (CE) is an economic model focused on using resources efficiently by minimizing waste and keeping materials in use for as long as possible[2]. Unlike the traditional linear system of "take, make, dispose," CE promotes a closed-loop approach where products and materials are reused, repaired, or regenerated. It's designed to reduce the demand for raw resources while delivering both environmental and economic benefits. At its core, CE aims to create systems that restore rather than deplete—using strategies like cradle-to-cradle design and high-value material recovery to close the loop on consumption.

2.2 Urban Metabolism Concept

UM is "the total sum of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste." [3]. It tracks the flow of materials, energy, people, and information through urban spaces to understand how cities function and grow. The goal is to measure these flows to improve efficiency, reduce environmental impact, and guide sustainable development. UM also explores deeper themes such as social equity, economic connections, and ecological transformation, positioning the city as an interconnected and evolving ecosystem. Figure 2 shows urban metabolism concept is adapted from the Circular Urban Metabolism Framework by Giulia Lucertini and Francesco Musco[1].

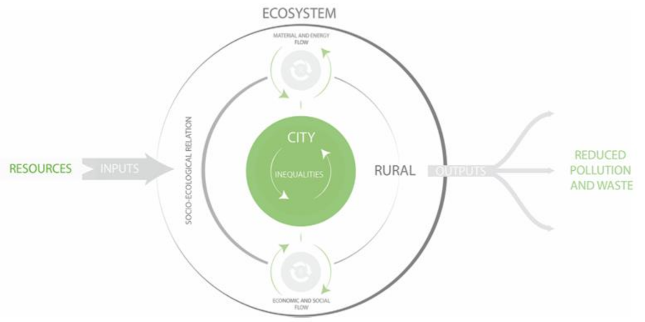


Fig -2 : Framework for urban metabolism

Urban metabolism is assessed using two key approaches: accounting tools that measure resource flows, and indicators that help interpret impacts over time.

Accounting Approaches:

- Material Flow Analysis (MFA): Tracks how materials enter, move through, and leave a city to identify usage patterns and losses.
- Exergy Analysis: Measures how much useful energy is available in a system.
- Energy Analysis: Calculates both direct and indirect energy used in urban processes.
- Input-Output Analysis: Maps the exchange of goods and services between sectors, highlighting economic and resource connections[4][5].

Indicator-Based Approaches:

- Ecological Footprint: Estimates the land area needed to support a population's resource use.
- Life Cycle Assessment (LCA): Evaluates the full environmental impact of products—from production to disposal.
- System Dynamics: Examines how complex systems evolve over time, helping to shape long-term urban strategies.

2.3 The similarities and differences between urban metabolism and circular economy

Urban Metabolism and Circular Economy both focus on using resources smarter and cutting down waste. This section looks at how they connect—and where they differ.

Table -1: The similarities and differences between urban metabolism and circular economy

Aspect	**Urban Metabolism (UM)**	**Circular Economy (CE)**
Definition	Focuses on quantifying and analyzing resource flows in cities, likening them to the metabolic processes of organisms.	Aims to design systems that minimize waste and maximize resource reuse through closed-loop cycles.
Scope	Descriptive and analytical framework for understanding urban resource consumption and waste production.	Prescriptive framework emphasizing actionable strategies for reducing resource inputs and waste outputs through reuse, recycling, and efficiency.
Focus Areas	Systematic studies of inputs and outputs, used for monitoring and evaluation.	Emphasizes strategies like industrial symbiosis, remanufacturing, and material recirculation for system redesign.
Approach	Analytical and diagnostic, focuses on studying resource flows within cities.	Action-oriented, seeks to design and implement sustainable business and production practices.
Role of Waste	Waste is analyzed as part of the city's overall resource flow.	Waste is minimized through design, reuse, and recycling to close material loops.
Framework	UM provides the foundational data for CE by measuring material flows and inefficiencies in urban systems.	CE can use UM data to guide the implementation of circular strategies in cities.

Policy and planning	UM data helps evaluate resource flows, providing a basis for developing effective CE strategies.	CE strategies, like recycling and industrial symbiosis, can be modeled using UM to predict outcomes and optimize resource use.
Practical Application	UM insights help identify areas for CE interventions, like resource recovery and waste reduction..	CE principles, informed by UM data, can be applied to create more sustainable urban systems.

3. WASTE TO ENERGY PLANT

Waste-to-Energy (WtE) plants convert non-recyclable municipal waste into usable energy—like electricity, heat, or fuel. These systems help reduce landfill use while recovering energy from trash that would otherwise go to waste[6]. There are two main approaches:

- **Thermochemical methods** (like incineration, gasification, and pyrolysis) use high temperatures to convert dry waste into energy. Incineration is the most common, often sterilizing harmful pathogens in the process. These methods are widely used in Europe for their efficiency[7].
- **Biochemical methods** (like anaerobic digestion and fermentation) use microbes to break down wet, organic waste—such as food scraps—producing biogas that can be used as fuel. This approach is especially effective when waste is well-sorted and biodegradable[7].
- WtE plants are particularly useful in areas with limited landfill space. While they help manage waste and generate energy, they can pose challenges in recycling and environmental impact.

According to the Solid Waste Management (SWM) Rules, 2016, several key responsibilities and operational standards have been outlined for waste handling and energy recovery:

- **Clause 15** outlines that local authorities are responsible for organizing and overseeing solid waste collection, transportation, and treatment within their jurisdiction.
- **Clause 18** mandates that industries located within a 100-kilometer radius of a refuse-derived fuel (RDF) or waste-to-energy facility must utilize such waste-based fuels where applicable.
- **Clause 21** states that non-recyclable waste with a calorific value of 1500 Kcal/kg or more must not be sent to landfills. Instead, it should be diverted toward energy recovery processes.

3.1 Multi-Criteria Decision-Making Methods and Their Role in WtE Planning

Multi-Criteria Decision Making (MCDM) methods are powerful tools for solving complex planning problems—especially in urban waste management and Waste-to-Energy (WtE) infrastructure. They help break down multifaceted issues into simpler, structured choices, making them ideal for evaluating diverse environmental, social, and economic factors.

The study highlighted the Analytical Hierarchy Process (AHP) as the most widely used method, valued for its simplicity and ability to rank alternatives based on clear criteria[8]. However, more recent trends (2015–2019) show a shift toward hybrid approaches, combining AHP with methods like TOPSIS, PROMETHEE, and ELECTRE to handle more complex decision environments.

AHP still proves highly effective for site suitability analysis due to its transparent, step-by-step approach.

4. WASTE-TO-ENERGY IN THE CIRCULAR URBAN METABOLISM CONTEXT

Turning Waste into Energy: Waste-to-Energy (WtE) plants play a key role in resource recovery by converting non-recyclable waste into usable energy. This process supports the idea of circular urban metabolism, where waste is not discarded but reintegrated as a valuable input.

Creating Closed Loops: In a circular system, the goal is to keep resources flowing. WtE helps close the loop by producing not only electricity but also heat and by products that can serve other urban functions, like district heating.

Less Waste to Landfill: By transforming waste into energy, these plants reduce the pressure on landfills—making waste management cleaner and more efficient.

Smart City Planning: When WtE is included in urban planning, cities can build systems that treat waste as a resource—delivering energy and supporting other needs in a more integrated way.

People at the Center: Getting communities and stakeholders involved in the planning process helps build trust, encourages innovation, and ensures WtE projects meet local needs.

Policy Makes It Work: Strong, supportive policies can guide cities in blending WtE with broader circular economy goals—helping urban areas move toward more sustainable and resilient futures.

5. CASE STUDIES OF WASTE TO ENERGY PLANT

5.1 Waste to Energy plant in Sewden

Sweden stands as a global leader in waste-to-energy (WtE) technologies, effectively transforming waste into valuable energy and minimizing landfill usage. Nearly all waste is recycled or converted into energy, exemplifying a successful circular economy.WtE Technologies in Sweden:

- **Incineration with Energy Recovery:** Utilizes mass-burning and fluidized-bed techniques to efficiently convert waste into energy.
- **District Heating Integration:** WtE plants supply heat to residential and commercial sectors, exemplified by facilities in Stockholm and Gothenburg[9].
- **Flue Gas Cleaning Systems:** Advanced technologies that significantly reduce emissions, contributing to Sweden's minimal carbon footprint[10].

5.2 Waste to Energy plant in Jabalpur

The Jabalpur Waste-to-Energy (WtE) plant, developed by Essel Infra, has been recognized by the Ministry of Housing and Urban Affairs and CII as India's top project in the integrated MSW-to-energy category. The award highlights excellence in 3R practices, resource recovery, and sustainable waste management.

- **Cleaner Cities:** The plant has helped reduce littering and improved sanitation across Jabalpur.
- **Smart Waste Governance:** An Integrated Command and Control Center enables real-time monitoring and efficient waste handling.
- **Public Participation:** Mobile and web platforms allow citizens to report issues, enhancing engagement.
- **Technology Integration:** With over 276,000 RFID tags, the ICT-backed system optimizes door-to-door waste collection.
- **Energy Contribution:** Electricity generated supports the regional grid through MP Power Management Company.
- **Zero Landfill Goal:** Advanced incineration technology minimizes landfill use and prevents groundwater contamination.

6. CASE STUDIES OF MATERIAL FLOW ANALYSIS

6.1 Comparative Evaluation of MFA Application and Waste-to-Energy Strategies in Sri Lanka (Western Province) & Serbia

Material Flow Analysis (MFA) is a vital tool for tracking waste generation, movement, and recovery. This study compares its implementation in Sri Lanka's Western Province and Serbia.

Table -2: Material Flow Analysis (MFA) Utility

Aspect	Sri Lanka (Western Province)	Serbia
MFA Objective	Track waste from source to final disposal, quantify flows	Identify inefficiencies, optimize WTE options
Data Depth	Detailed household-level data on waste composition and flow	Limited, hindered by infrastructure and data gaps
Waste Breakdown	Quantified MSW into recoverables (compost, paper, plastic)	High biodegradables (~60%), poor calorific value
Recovery Matrics	MRF and ERF calculated to evaluate material & energy recovery	Used to inform suitable WTE tech (e.g., anaerobic digestion)

Table -3: Waste-to-Energy (WTE) Implementation

Factor	Sri Lanka (Western Province)	Serbia
Current Status	Operational WTE (~600 tons/day), RDF used	Limited WTE infrastructure; mostly landfilling
Energy Recovery	Calculated ERF, energy conversion from MSW	Potential via anaerobic digestion & landfill gas
Infrastructure Readiness	Partial (needs composting/source segregation)	Inadequate, needs investment and modernization
Technology Fit	Incineration + RDF	Anaerobic digestion fits waste profile (wet/organic)

- MFA is Crucial: Both studies highlight the importance of MFA in measuring waste flow, identifying inefficiencies, and optimizing recovery, particularly in the context of Waste-to-Energy (WTE).
- Circular Economy Requires Grassroots Engagement:
  - Sri Lanka has made promising progress but requires wider implementation of composting, recycling, and public awareness initiatives.
  - Serbia aligns its policies with EU standards but must focus on enforcement, financial mechanisms, and gaining public support to make the circular economy a reality.

7. CASE STUDIES OF SITE SUITABILITY USING ANALYTICAL HEIRARCHY METHOD

7.1 Jos Metropolis

Jos, located in Nigeria's middle belt, is undergoing rapid urban growth, with a population increase of 5.5% annually. The city currently produces around 221 tons of municipal waste daily, projected to rise to 299 tons by 2032—highlighting the urgent need for sustainable waste management solutions. Approach & Methodology:

The study used the Analytical Hierarchy Process (AHP) within a GIS-based framework to evaluate suitable locations for a Waste-to-Energy (WtE) facility. Key factors considered included proximity to roads, rivers, power substations, land cover, and slope.[11]

- Data was gathered from diverse sources such as Sentinel-2 satellite imagery, SRTM for elevation, and Open Street Map for infrastructure mapping.
- A pairwise comparison matrix helped determine the relative importance of each factor, and a Consistency Ratio (CR) of 0.07 validated the reliability of the judgment matrix.
- The final output was a suitability map created using weighted overlay analysis in ArcGIS.

This case clearly demonstrated how AHP and GIS can guide smart, cost-effective urban planning, especially when integrating WtE solutions into the broader **circular** urban metabolism framework.

8. ANALYSIS

8.1 Waste to Energy Plant in India : Challeneges and impacts

Waste-to-Energy (WtE) projects in India often struggle due to mixed and low-quality waste, frequent technical issues, high emissions, and financial setbacks. By studying and analyzing waste-to-energy systems in India, as outlined in [12], the associated impacts and challenges become more understandable. Many plants face legal battles and public opposition, driven by health and environmental concerns. With poor energy recovery and inefficient resource use, several initiatives have collapsed or remained non-operational. These challenges underline the need for smarter planning, better waste segregation, and stronger community involvement to make WtE a practical and trusted part of India's waste management strategy.

8.2 Site Suitability Using Analytical Hierarchy Method

- The integration of AHP with GIS-based MCA offers a structured, multi-criteria approach for identifying optimal Waste-to-Energy (WtE) sites.
- Site suitability is influenced by proximity to waste sources, infrastructure access, land use, topography, and environmental constraints—crucial for cost-effectiveness and sustainability.
- WtE planning should align with broader urban and energy policies, using spatial analysis to guide strategic, sustainable decisions.
- Incorporating stakeholder input, environmental data, and socio-economic factors can enhance future site assessments and promote inclusive planning.

9. FRAMEWORK FOR THE WASTE TO ENERGY PLANT

Conceptual framework for waste to energy plant in the context of circular urban metabolism is shown in the figure 4 by author generated

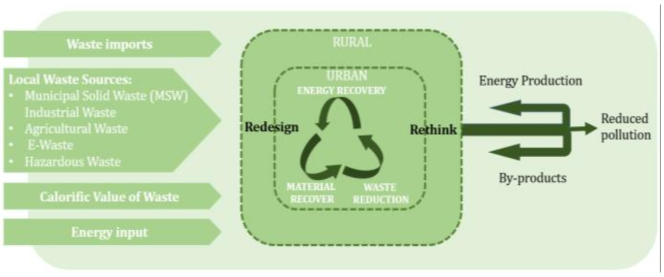


Fig -3 : Framework for Waste to Energy Plant

9.1 Waste Input Assessment

Material Flow analysis: MFA helps quantify and track waste materials from their sources to disposal or treatment. This is fundamental in understanding the types and quantities of waste available for energy recovery.

Amount of Waste: Identify the volume of Municipal Solid Waste (MSW) generated within the targeted region.

Waste Composition: Analyze the breakdown of waste types.

Mass Balance Equation: $\sum Ik = \sum Ok + \sum Sk$

Where Ik : Inputs (waste collected) ; Ok: Outputs (energy produced) ;Sk : Storage or residuals (landfill, ash).

9.2 Energy Production and Consumption Analysis

- Emergy Analysis: Assess the available energy potential in different types of waste.
- Waste Characterization: Identify organic, recyclable, and non-recyclable waste.
- Calorific Value: Measure the energy content in the waste.
- Energy Potential = Waste Volume × Calorific Value
- Importance: Determines the suitability of waste for energy recovery and the expected energy output.

9.3 Site Suitability

Table -4: Parameters of site suitability

Environmental	Social and safety	Economic Factors
Settlement distance	Lowlands distance	Major road distance
River Distance	Sub stations	Local road distance
Sensitive areas distance	Future urban growth	Existing land use
Land slope	Waste dumpsites	
Land cover	Industries	
Agricultural area distance		

Method to follow:

- Analyze Relevant Parameters: Identify key parameters that determine site suitability.
- Map Creation: Develop a map for each parameter, indicating the proximity of suitable areas.
- Overlay Analysis: Overlay the individual maps to identify regions that are most suitable based on multiple parameters.(weighted index overlay analysis method)
- Selection of Optimal Area: From the identified suitable regions, evaluate and select the most appropriate site based on the relative importance of each parameter.
- Decision-Making Approach: Use the Analytical Hierarchy Process (AHP) for multi-criteria decision-making, assigning weights to the parameters and prioritizing the most important factors in site selection.

9.4 Waste Segregation and Pre-treatment

- Segregation at Source: Separate organic, recyclable, and combustible wastes to improve feedstock quality and WtE efficiency.
- Pre-treatment Requirements: Based on the type of WtE technology, assess pre treatment needs like shredding, drying and Refuse Derived Fuel (RDF) to Increase calorific value and reduce contaminants, which enhances combustion efficiency.
- RDF Usage (%) = (RDF output /Total combustible waste) ×100

9.5 Transportation and Logistics (efficient road network and optimize the routing to reduce fuel consumption)

- Transportation Infrastructure: Establish an efficient transportation network for waste collection, considering road access, fuel costs, and emissions.
- Logistics Management: Develop a schedule and routing system for waste collection and delivery to the WtE plant to minimize fuel use and optimize resource allocation.

9.6 Operational and Maintenance Considerations

- Continuous Monitoring Systems : Install sensors and real-time monitoring to track energy output, emissions, and operational efficiency.
- Maintenance Scheduling : Plan regular maintenance to reduce downtime and ensure the plant meets regulatory and performance standards.

9.7 Economic Feasibility and Funding

- Cost-Benefit Analysis : Conduct financial assessments of operational costs versus energy revenues and carbon credits.
- Government Support and Subsidies : Identify opportunities for financial assistance, grants, or incentives to offset capital and operational costs.

9.8 Environmental and Social Impact Mitigation

- Emission Control: Implement air pollution control measures, such as scrubbers and filters, to comply with environmental standards.
- Public Awareness and Engagement: Develop programs to engage the community on waste management practices and the benefits of WtE plants to foster support.

9.9 Calculations of Recovery and Losses

- Recyclable Material Recovery: $R=(\sum(P+T+Pl+M+G+Cm) / a) \times 100$; where P, T, Pl, M, G and Cm represent different recyclable materials, and a is the total waste generated.
- Waste-to-Energy Recovery Factor : E= (Energy produced from waste / Total organic waste) × 100
- Composting Factor : C=(Composted Waste Volume / Total Organic Waste)×100
- These metrics gauge efficiency in waste-to-material or energy conversion.

9.10 Monitoring and Continuous Improvement

- Efficiency Calculations: η = (Energy output / Energy input) ×100

10. CONCLUSIONS

This study highlights how integrating Waste-to-Energy with Circular Urban Metabolism can turn urban waste into a valuable resource. With community support and smart planning, cities can reduce pollution, generate clean energy, and build a more sustainable, resilient future.

REFERENCES

[1] G. Lucertini and F. Musco, “Circular urban metabolism framework,” *One Earth*, vol. 2, no. 2, pp. 138–142, 2020, doi: 10.1016/j.oneear.2020.02.004.

[2] P. Morseletto, “Targets for a circular economy,” *Resources, Conservation and Recycling*, vol. 153, p. 104553, 2020.

[3] T. L. Sanches and N. V. S. Bento, "Urban metabolism: A tool to accelerate the transition to a circular economy," in *Sustainable Cities and Communities*, W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar, and T. Wall, Eds. Cham, Switzerland: Springer, 2020, pp. 860–876.

[4] A. Allesch and P. H. Brunner, “Material flow analysis as a decision support tool for waste management,” *ACS Publications*, 2017, doi: 10.1021/acs.est.7b02232.

[5] N. A. Hemali and A. A. P. De Alwis, “Application of material flow analysis to municipal solid waste in urban areas in developing countries and possible solutions under circular economic framework,” Nature Environ. Pollut. Technol., vol. 21, no. 3, pp. 1411–1419, 2022.

[6] Cucchiella, F., D’Adamo, I., & Gastaldi, M., "Sustainable waste management: Waste to energy plant as an alternative to landfill," *Energy Conversion and Management*, vol. 131, pp. 18-31, 2017, doi: 10.1016/j.enconman.2016.11.012.

[7] K. A. Karmakar, T. Daftari, K. Sivagami, M. R. Chandan, A. H. Shaik, B. Kiran, and S. Chakraborty, "A comprehensive insight into waste to energy conversion strategies in India and its associated air pollution hazard," *Environmental Technology & Innovation*, vol. 29, p. 103017, 2023, doi: 10.1016/j.eti.2023.103017.

[8] A. Darko, A. P. C. Chan, E. E. Ameyaw, E. K. Owusu, E. Pärn, and D. J. Edwards, "Review of application of analytic hierarchy process (AHP) in construction," *J. Facil. Manage.*, vol. 26, no. 4, pp. 436-452, Mar. 2018, doi: 10.1080/15623599.2018.1452098.

[9] CTCN, “Filborna Combined Heat- and Power Plant,” *Climate Technology Centre & Network*, 2015.

[10] Smart City Sweden, “Renova – Global Forefront Waste Technology for Heat and Power,” *Smart City Sweden*, 2019.

[11] O. I. Alubo and M. Isma’il, “Site suitability analysis for waste to energy facility in Jos Metropolis, Plateau State, Nigeria,” *Dutse J. Pure Appl. Sci.*, vol. 9, no. 2a, pp. 1–10, 2023.

[12] Centre for Financial Accountability**,** *India’s Waste-to-Energy Paradigm: A Policy, Environmental and Social Perspective*, New Delhi, India: Centre for Financial Accountability, Dec. 2022.

[13] A. Karmakar, T. Daftari, K. Sivagami, M. R. Chandan, A. H. Shaik, B. Kiran, and S. Chakraborty, “A comprehensive insight into waste to energy conversion strategies in India and its associated air pollution hazard,” Environ. Technol. Innov., vol. 29, p. 103017, 2023.

[14] W. A. Qazi, M. F. M. Abushammala, M.-H. Azam, and M. K. Younes, “Waste to-energy technologies: A literature review,” J. Solid Waste Technol. Manag., vol. 44, no. 4, pp. 387–409, 2018.

[15] D. N. Markic, H. S. Carapina, D. Bjelic, L. S. Bjelic, P. Ilic, Z. S. Pesic, and O. Kikanovicz, “Using material flow analysis for waste management planning,” *Pol. J. Environ. Stud.*, vol. 28, no. 1, pp. 255–265, 2019, doi: 10.15244/pjoes/78621.

[16] H. Corvellec, T. Bramryd, and J. Hultman, "The business model of solid waste management in Sweden – a case study of two municipally-owned companies," Waste Manag. Res., vol. 30, no. 5, pp. 512–518, May 2012, doi: 10.1177/0734242X11427944.

[17] H. Rylander, "Waste Management in Sweden. A National Report," Sage Journals, 1985.